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potential evaporation and potential transpiration at Kew in 1976 in relation to the 1964-70 average.

B G Wales-Smith

1. Introduction.

It has been shown (Wales-Smith, 1979a) that average monthly totals of potential transpiration ^{E_{t100} (representing short grass)} for the period 1964-70 at Kew, obtained from a combination equation including:

- (a) month-by-month variation of the bulk aerodynamic and stomatal resistances,
- (b) a catchment aerodynamic roughness parameter,
- (c) allowance for net soil heat flux and
- (d) adjustment of the Penman-Brunt long-wave radiation term

are significantly smaller than Penman's (1948) E_{tp} in summer. It has been stressed that if potential transpiration is to be rigorously calculated (as in this case) it is essential to make realistic estimates of the amounts of intercepted rainfall evaporated when calculating changes in potential and actual soil moisture deficits.

Because it was decided to use either the combination equation given in Wales-Smith (1979) or one essentially equivalent to it in a variety of agricultural and hydrological studies and services, including MORECS (Wales-Smith, Prior and Arnott, 1976) ^{Wales-Smith and Arnott (1979)} it is necessary to ensure that an extreme drought, such as that of 1976, is adequately represented in terms of the development of large soil moisture deficits during very dry weather when potential evaporation (from wet vegetation, etc) makes very little contribution to the total of potential evaporation and potential transpiration.

2. Calculations.

Values of Penman's (1948) E_{tp} were calculated for Kew for each month in 1976. Values of potential transpiration from the new combination equation (E_{t100}) were also calculated, using the monthly values of $\frac{G_{s0n}}{r_a} \cdot 0.95B$ and G from Table 4a of Wales-Smith (1979). The calculations for E_{t100} are set out in Table 1 (of the present paper). Accumulated totals of $(E_{t100} - R)$, where R = rainfall, were calculated through the year and values of $(E_{tp} - R)$ were calculated from March onwards (when that quantity began to take positive values).

The monthly fractions of 24-hour rainfall and potential transpiration adopted for day and night in Wales-Smith (1979a) Table 5, are reproduced, here, in Table 2 and

* representing a typical lowland English catchment.

have been used to apportion the 1976 values of both quantities between day and night. The values of "Max poss r_i ", where r_i = intercepted rainfall, were obtained from the same source (lines 56 and 7) multiplied by the number of days in each month. These extreme limits are based on the assumption that the maximum possible totals of intercepted rainfall occurred every day and every night in each month.

A month's value of $E_{w(\text{day})}$ was not allowed to exceed the product of the corresponding value of $E_{t(\text{day})}$ and the appropriate ^{inverse} value of $\frac{\Delta + \gamma}{\Delta + (1 + r_{\text{sn}}/r_a)\gamma}$ given in Table 1, or to exceed the value of "max poss $r_i(\text{day})$ ". Each value of $E_{w(\text{day})}$ adopted was recorded and then multiplied by $\frac{\Delta + (1 + r_{\text{sn}}/r_a)\gamma}{\Delta + \gamma}$ and subtracted from $E_{t(\text{day})}$ to give the real total of potential transpiration $E_{t(\text{resid})}$.

The value of $E_{w(\text{night})}$ was constrained in the same way. Night-time residuals of " E_t " are meaningless (as stomata are closed) and were ignored.

Accumulated totals of $(E - R)$ were calculated. $E = E_{t(\text{resid})} + E_{w(\text{day})} + E_{w(\text{night})}$

3 Comparisons and deductions.

Monthly value of E_t , E_t and E are compared in Figure 1. It can be seen that E_{tp} is lower than the other two, as would be expected. Monthly values of the energy balance and ventilation contributions to E_t for 1976 are compared with 1964-70 averages of the same quantities ^{in Figure 2.} Wales-Smith (1979b) has shown that this period is typical of the standard climatological period 1931-60. It can be seen that ventilation effect made a very large contribution to E_t in the extreme drought summer.

It has been shown that although allowance must be made for the evaporation of intercepted rainfall in average years, the new combination equation produces the very large totals of potential transpiration appropriate to drought summers thanks to the powerful contribution made by the ventilation - advection effect under such conditions.

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Table 1.

Calculation of E_{t100} , $\sum E_{t100}-R$ and $\sum E_{tP}-R$ for Kew
in 1976

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
$r_{50m} / r_{2,100}$	1.20	1.37	1.09	0.75	0.71	0.64	0.59	0.59	0.57	0.75	1.18	1.18	$P_{50} \frac{1}{2} = 100$
Δ	.655	.612	.627	.748	.996	1.355	1.431	1.304	1.048	.903	.679	.527	
$\Delta + (1 + r_{50m} / r_{2,100}) \delta$	2.107	2.176	2.006	1.903	2.125	2.437	2.480	2.353	2.084	2.058	1.458	1.306	
$\Delta / \Delta + (1 + r_{50m} / r_{2,100}) \delta$	.311	.281	.313	.393	.469	.556	.577	.554	.503	.439	.466	.403	
$(1-r) RCP$	23.9	31.3	77.8	129.3	162.4	185.4	191.0	165.5	86.4	45.3	27.0	20.1	
$.958 RLP$	40.1	26.2	55.2	70.9	71.4	74.7	82.0	85.1	49.9	34.0	36.9	39.9	
G	6.0	3.3	-1.3	-7.3	-10.3	-11.0	-9.3	-3.0	3.7	9.0	11.2	9.0	
$\{(1-r) RCP - .958 RLP + G\}$	-10.2	8.4	21.3	51.1	80.7	99.7	99.7	77.4	40.2	20.3	1.3	-10.8	
$\frac{\Delta}{\Delta + (1 + r_{50m} / r_{2,100}) \delta} \{ \}$	-3.2	2.4	6.7	20.1	37.9	55.4	57.5	42.9	20.2	8.9	0.6	-4.3	
$\frac{2.5\delta}{\Delta + (1 + r_{50m} / r_{2,100}) \delta}$	.783	.758	.823	.867	.776	.677	.665	.701	.792	.802	1.132	1.263	
E_{5P}	45.9	22.3	50.5	62.1	93.0	135.3	160.9	129.6	57.0	31.0	17.1	11.8	
$\frac{2.5\delta}{\Delta + (1 + r_{50m} / r_{2,100}) \delta} E_{5P}$	35.9	16.9	41.6	53.8	72.2	91.6	107.0	90.9	45.1	24.9	19.4	14.9	
E_{t100}	32.7	19.3	48.3	73.9	110.1	147.0	164.5	133.8	65.3	33.8	20.0	10.6	859.3
E_{tP}	14.6	13.7	37.7	62.5	95.8	123.8	131.3	102.5	47.1	20.7	3.8	-2.5	(625.2 MAR NOV)
$E_{tP} \{ \frac{E}{E_{tP}} \}$	39.7	20.4	48.6	71.9	100.6	134.9	145.7	117.9	60.3	35.2	10.0	/	
$A + \delta$	1.315	1.272	1.287	1.408	1.656	2.015	2.091	1.964	1.708	1.563	1.339	1.187	
$\frac{A + \delta}{A + (1 + r_{50m} / r_{2,100}) \delta}$	.624	.585	.642	.740	.779	.827	.843	.835	.820	.759	.918	.909	
R	14.8	20.9	8.8	9.5	27.2	7.9	24.0	13.5	106.6	95.4	81.9	66.8	477.3 (374.8) MAR NOV
$\sum E_{t100} - R$	17.9	16.3	55.8	120.2	203.1	342.2	482.7	603.0	561.7	500.1	438.2	382.0	
$\sum E_{tP} - R$	0	0	28.9	81.9	150.5	266.4	373.7	462.7	403.2	328.5	250.4	/	

Authority and Remarks

Table 2.

Table 2.
Values of Rainfall, estimated intercepted rainfall and estimated potential evaporation at Kew, 1976 (Also $\Sigma(E-R)$)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Fraction of r by day	.33	.42	.49	.67	.75	.85	.85	.75	.67	.54	.37	.33	
" " night	.67	.58	.51	.33	.25	.15	.15	.25	.33	.46	.63	.67	
Fraction of E_t by day	.69	.71	.86	.92	.93	.91	.92	.94	.97	.93	.72	.64	
" " night	.31	.29	.14	.08	.07	.09	.08	.06	.03	.07	.28	.36	
r_{day}	4.9	8.8	4.3	6.4	20.4	6.7	20.4	10.1	71.4	51.5	30.3	22.0	
r_{night}	9.9	12.1	4.5	3.1	6.8	1.2	3.6	3.4	35.2	43.9	51.6	44.8	
E_{t100}	32.7	19.3	48.3	73.9	110.1	147.0	164.5	133.8	65.3	33.8	20.0	10.6	
$E_{t100}(day)$	22.6	13.7	41.5	68.0	102.4	133.8	151.3	125.8	63.3	31.4	14.4	6.8	
" $E_{t100}(night)$ "	10.1	5.6	6.8	5.9	7.7	13.2	13.2	8.0	2.0	2.4	5.6	3.8	
Max. poss r_i (day)	5.1	9.4	15.2	36.2	53.1	63.7	65.9	63.1	36.2	15.2	8.9	5.1	
" r_i (night)	10.4	13.0	15.8	17.8	19.4	12.3	11.6	19.4	17.8	15.8	15.1	10.4	
$E_w(day)$	4.9	8.8	4.3	6.4	20.4	6.7	20.4	10.1	36.2	15.2	8.9	5.1	
$E_{t(resid)}$	19.5	8.6	38.7	63.3	86.5	128.3	134.1	117.4	33.6	19.9	6.2	2.2	
$E_w(night)$	9.9	9.6	4.5	3.1	6.8	1.2	3.6	3.4	2.4	3.2	6.7	2.4	
E_{100}	34.3	27.0	47.5	72.8	113.7	136.2	158.1	130.9	72.2	38.3	21.8	9.7	862.5
R	14.8	20.9	8.8	9.5	27.2	7.9	24.0	13.5	106.6	95.4	81.9	66.8	477.3
$\Sigma(E-R)$	19.5	25.6	64.3	127.6	214.1	342.4	476.5	593.9	559.5	502.4	442.3	385.2	

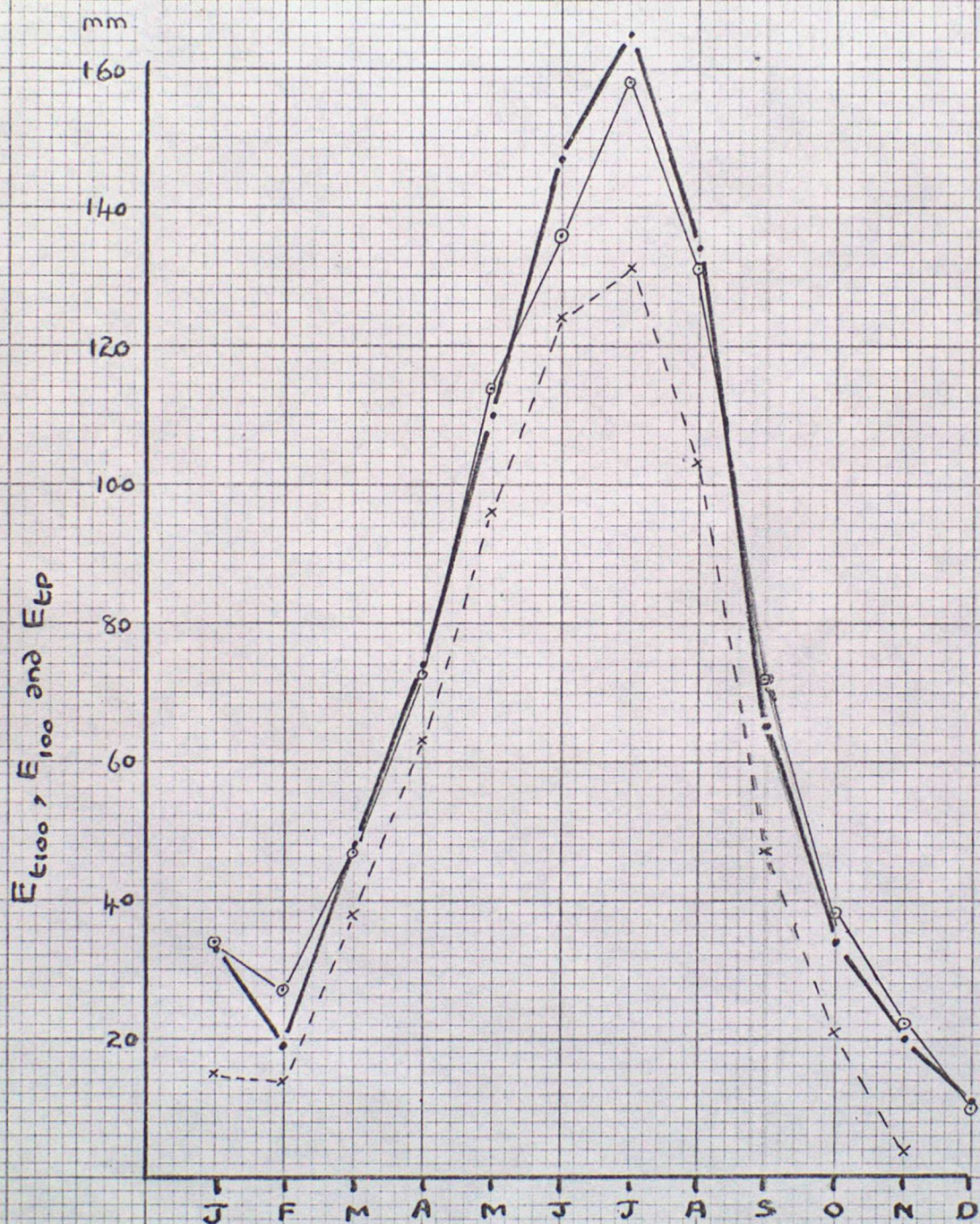


Figure 1.

—•— E_{t100}
 ○—○ E_{100}
 x---x E_{tp}

Three measures of evaporation
 at Kew in 1976

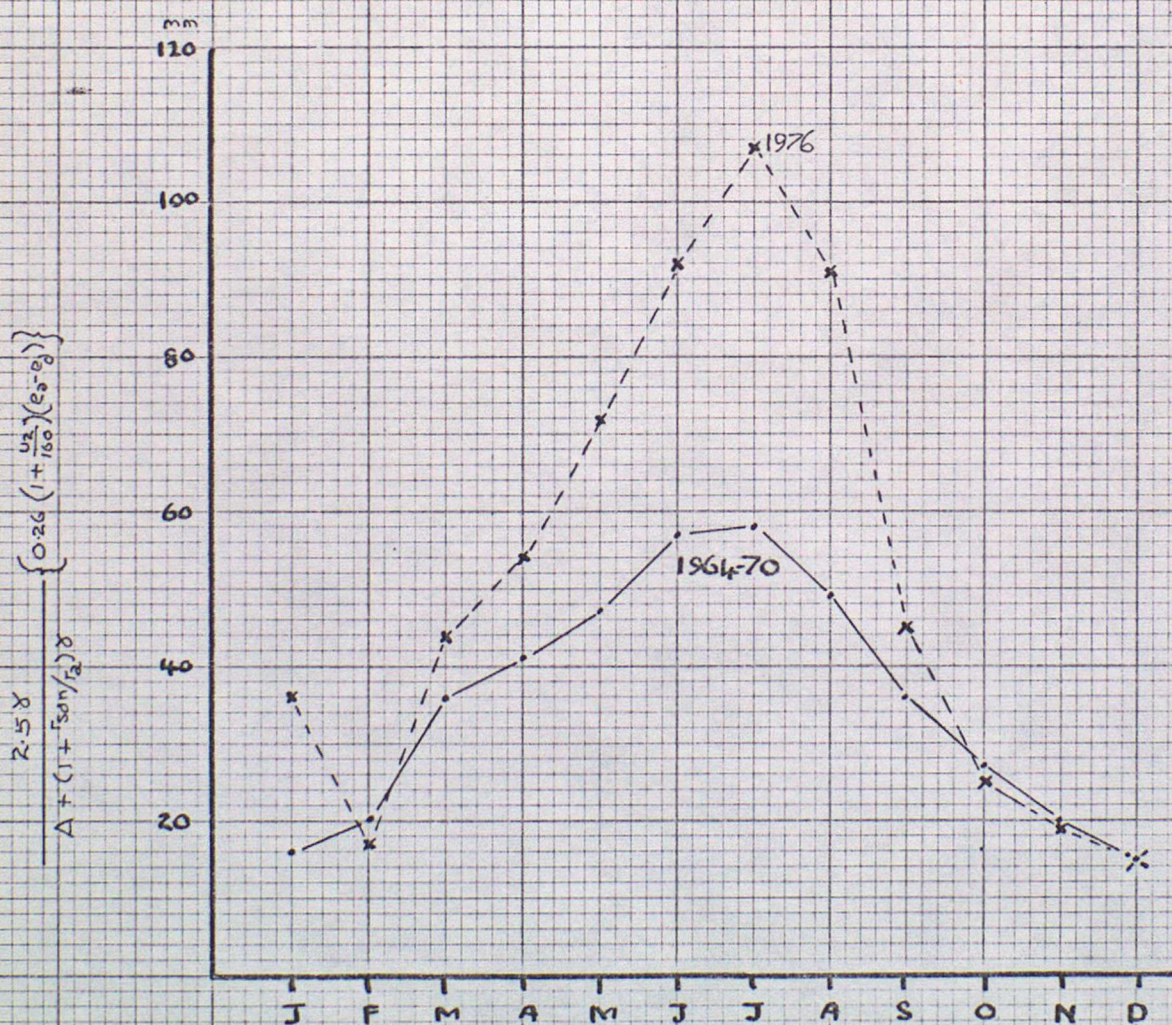
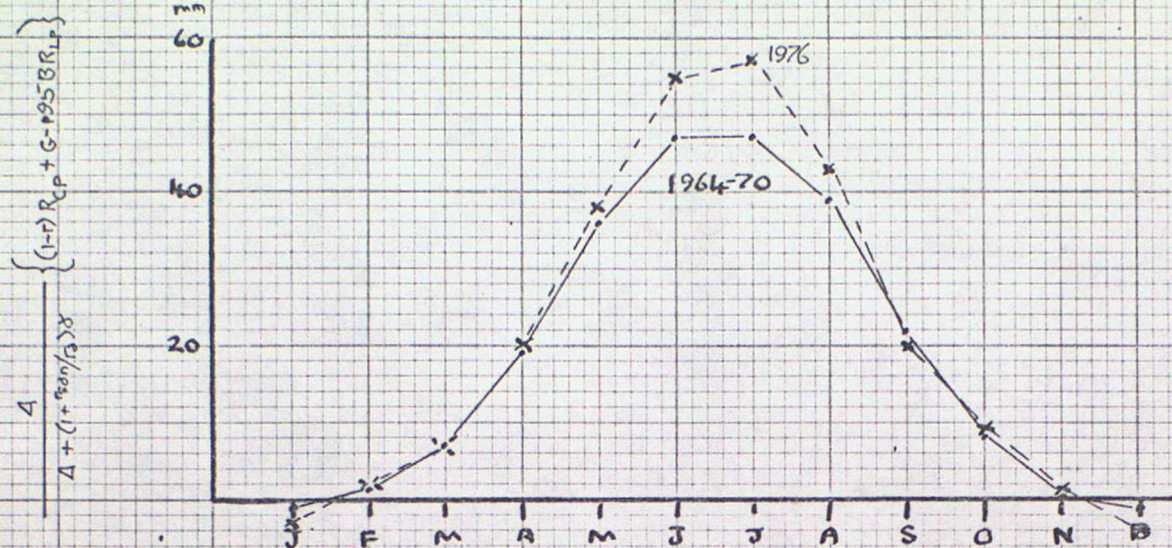


Figure 2. The energy balance and ventilation contributions to potential transpiration E_{t100} from a typical English lowland catchment for 1964-70 and 1976. (Calculations made with data from Kew.)